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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements in Bearings

I, CHARLES WALTER MCCUTCHEN, a citizen of the United States of America, of Cavendish Laboratory, Cambridge, Cambridgeshire, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:—

THIS INVENTION relates to improvements in bearings and has for its object the provision of a new or improved bearing affording low running friction combined with low starting friction.

According to the present invention there is provided a bearing between two relatively movable members, such bearing comprising at least one element of compressible resilient material carried by at least one of said members, the material of such element having therein cavities or channels containing liquid lubricant and opening at a surface remote from the member by which the element is carried, the said surface forming a bearing surface or having thereon a permeable membrane which forms a bearing surface, the arrangement being such that the said element is compressed and the said bearing surface is loaded into engagement with the other of said members or an element thereon, the cavities or channels being such that the lubricant is held therein sufficiently to ensure that the load is borne largely by the lubricant.

In one preferred form of the bearing according to this invention, the or each element may be formed of a closed cell sponge rubber or similar sponge material based on synthetic resinous material. Such form of bearing may be constructed by trimming a block of the closed cell sponge material along a surface in the body of the block intersecting cells therein.

I have found that sponge rubber or similar sponge material based on synthetic resinous material and having closed cells, when cut so as to present opened cells is capable of holding lubricant, for example soapy water, so that, when such a sponge material is drawn across a surface of glass, steel or other material, the coefficient of friction is extraoridinarily low because the load is borne largely by the liquid in the cut cells. If the rubbing is continued, say for an hour, the co-efficient of friction rises somewhat as the liquid leaks out between the glass and the sponge, but is restored to substantially the original value by removing the sponge from the surface to which it has been applied and re-applying it. Such sponge material with open cells on the bearing side thus constitutes a hydrostatic bearing. In such bearings it is important that the fluid-filled cavities extend all the way to the rubbing surface. Behind these open cells, closed cells improve the resilience. Furthermore, when such a bearing is made by cutting a spong comprising only closed pores, lateral exudation of lubricant when the bearing is under load is avoided or minimised.

According to a further feature of this invention, a sponge material with closed cells which has been cut to provide opened cells on one surface may be pierced in a direction transverse to such a surface so that channels lead into the body of the material from such surface and interconnect cells opening at the latter with other cells within the material. Advantageously, most or all of the originally closed cells are put into communication with said surface. By this means most or all of the liquid in the sponge is available for making up seepage of lubricating liquid along the rubbing surfaces. Preferably the piercing is not carried to the extent of piercing the back surface of the sponge. This arrangement provides a unique bearing surface in that it is permeable to lubricating liquid in a direction transverse to the bearing surface but impermeable to lubricating liquid in a direction parallel to the bearing surface.

[*Price 4s. 6d.*]

It is not, however, necessary that the material be permeable in the single direction perpendicular to the bearing surface. A resilient material which is permeable in all directions may be used provided that the permeability is so low as to minimise side leakage under load. If the bearing surfaces are smooth, there will be sufficient exuded lubricant to maintain a film thick enough to avoid heavy contact between the rubbing surfaces. This type of bearing may be called a "weeping" bearing.

As already indicated, the sponge material may be sponge rubber or sponge made from a synthetic rubber, for example polychloropropane, or from other synthetic resinous material capable of being formed into sponge, for example polyurethanes. The pore size is not critical in the sense that it can be varied in accordance with the load which the bearing is to carry, but, as will be appreciated, the pore size must be such as to ensure that lubricant is held sufficiently for the load to be borne largely by the lubricant.

In another convenient form of the bearing according to this invention, the element or elements may be made starting from a sponge with closed cells and piercing the sponge at a large number of points from the surface of the structure which is to constitute the bearing surface or to receive the membrane forming the bearing surface. The piercing may be such as to open only those cells which are immediately adjacent such surface or alternatively may go deeper into the sponge material so as to make available, as described above, the lubricant content of all or most of the cells in the sponge. Again such piercing preferably does not extend through the face of the sponge opposite to the bearing surface.

A still further alternative form of bearing may be made from a material having a regular cellular structure, the cells opening at the surface and having parallel axes which extend perpendicularly to the bearing surface The cells may be of any cross section, e.g. square, circular or hexagonal. In constructing a bearing in accordance with the present invention from such a material one end of the cell structure is entirely sealed. This leaves a structure with the bearing surface presenting a series of open cells transverse to the bearing surface. Such structures may be made from any suitable material and preferably a synthetic resinous material having some rigidity, for example materials made from linear condensation polymers such as polyamides. It is not essential that the walls of the cells be strictly parallel, indeed for some purposes it is of advantage both as regards manufacture and in use that the cells have a cross-section which decreases in area in a direction away from the bearing surface. Such a structure lends itself very readily to formation by injection moulding. This type of cellular structure is porous in the direction perpendicular to the bearing surface and substantially non-porous to the lubricant in the transverse direction.

As indicated the bearing surface may be formed by a permeable membrane, the pore size of which is capable of permitting passage of the lubricant and which covers a surface of the element at which cavities or channels therein emerge. Such a porous membrane may be made with any suitable material, for example nitrocellulose, polyvinyl alcohol or other polyvinyl compound, or even of the same type of material as that constituting the sponge proper. A bearing having this feature has the property of being able to exude from the membrane side a small quantity of lubricant which reduces its coefficient of friction when in contact with any smooth surface, the pores in the material behind the permeable membrane acting as a reservoir for further lubricant. This type of bearing is thus another kind of "weeping" bearing.

The bearings according to this invention, may be applied to sleeve bearings for shafts, thrust bearings or any other type of bearing to which the wellknown porous metal technique has been applied. Since, as previously stated, the coefficient of friction tends to rise with continued use of the bearings according to this invention, they are more particularly applicable to machines where the load is intermittent, for example machines in which a shaft is carried by a main bearing and a floating bearing designed to damp out precession. The latter bearing would be advantageously constructed in accordance with the present invention. The term "intermittent load" is used in this specification to include the case where the load is truly intermittent and also the case where the load is intermittently very low, e.g. in slow running. In applying the bearing of this invention to a shaft or like member normally giving a continuous load, the construction may be adapted so as to give a load with respect to any particular portion of the bearing surface is intermittent by providing the external surface of the shaft within such a bearing with smooth axial grooves or, in the case of a thrust bearing, by providing the bearing surfaces of the thrust collar of the shaft with radial grooves, the grooves preferably having smoothly rounded edges.

Bearings, according to the present invention, for use as shaft bearings may be simple pads arranged at intervals in a main metal bearing so as to contact the shaft at intervals round its periphery. Alternatively, the bearing may be a continuous pad, that is to say an annulus, inside the main metal bearing. If desired, particularly in the case of the weeping bearings, i.e. those carrying permeable membranes, both bearing surfaces may be provided with the new type of bearing. For

example, a sleeve bearing may be lined on the inside with such a bearing and, in addition, the shaft itself may have such a bearing surface applied to it, for example, within a groove cut for the purpose in the shaft.

In order that this invention may more readily be understood, reference will now be made, by way of example, to the accompanying drawings in which:—

Figures 1 to 4 are cross-sections through four different forms of bearing element for use in bearings according to this invention;

Figure 5 is a plan view of a fifth form of bearing element:

Figure 6 is a cross-section on the line VI—VI of Figure 5;

Figures 7 and 8 are fragmentary longitudinal sections through two forms of shaft bearing according to this invention;

Figure 9 is a fragmentary cross-section through a modified form of the bearing of Figure 7; and

Figure 10 is a fragmentary section through a Michell or Kingsbury tilting pad thrust bearing according to this invention; and

Figure 11 is a fragmentary section in a plane at right angles to the plane of the section of Figure 10 and illustrating a modification of the bearing of that Figure.

Referring to Figure 1, there is illustrated an element for a bearing according to this invention, such element comprising a rectangular parallelepipedonal block 1 of a sponge rubber or similar sponge material based on synthetic resinous materials and having closed cells 2, the block having been cut along a surface parallel to one of its faces to provide a surface 3 at which some of the cells 2 open and which forms the bearing surface of the bearing.

Figure 2 shows a similar element in which the bearing surface is formed by a membrane 4 which covers the surface 3 and which is permeable to the lubricant to be used in the bearing so as to form an element for a "weeping" bearing.

Figure 3 shows an element similar to that of Figure 1, but in which piercing members, e.g. pins, have been pressed into the surface 3 forming the bearing surface so as to provide channels 5 leading into the body of the material from the bearing surface and interconnecting the cells 2 which open at the latter with further cells 2 within the material. The channels 5 may extend any desired distance into the block 1 so as to connect more or less of the cells within the material with those opening at the bearing surface. As shown in the Figure, these channels do not penetrate through the surface 6 opposite to the bearing surface 3.

The element illlustrated in Figure 4 comprises a block 1 similar to that used to form the element of Figure 1, but which has not been cut to provide cells opening at the bearing surface. To connect cells 2 within the material with the bearing surface 3, the latter is pierced to provide channels 7 opening at the bearing surface and intersecting cells within the material. Such channels 7 may extend only a short distance into the block as shown in Figure 4 or may extend a longer distance, as the channels 5 of the element of Figure 3 so as to intersect more cells within the block.

Figures 5 and 6 illustrate a further form of element, this comprising a block 8 of a material similar to that used to form the block 1 of the elements of Figures 1 to 4, but having a regular cellular structure. As shown, the cells, indicated by the reference 9, open at a surface 10 which constitutes the bearing surface of the elements and have parallel axes extending perpendicularly to the surface 10. The cells 9 do not extend completely through the block and in this example have a hexagonal cross-section. For ease of manufacture, the cells 9 may taper, the cross-section decreasing away from the surface 10.

The elements of Figure 3, Figure 4 or Figure 5 and 6 may, if desired, have their bearing surfaces formed by a permeable membrane similar to the membrane 4 of the element shown in Figure 2 and covering the surface 3.

Figure 7 illustrates one form of shaft bearing according to this invention. The figure shows a shaft 11 journalled for rotation in a member 12 in the shaft bearing which is indicated generally by the reference 13. The bearing 13 incorporates an element similar to that shown in any of the preceding figures. The element, indicated by the reference 14, is of annular sleeve-like form and forms a liner to a metal sleeve 15 which is secured against rotation in a recess in the member 12. The bearing surface of the element 13 is the inner surface of the annulus and engages the external surface of the shaft 11.

A second form of shaft bearing is shown in Figure 8, this being similar to that of Figure 7, but having the external surface of the shaft 11 within the element 14 clad with a similar element 16. Preferably, as shown, the element 16 is recessed into the outer surface of the shaft 11.

Figure 9 illustrates a modification of the bearing of Figure 7 in which the surface of the shaft 11 is, at a position within the element 14, provided with axial grooves 17 which ensure that, as the shaft rotates, all parts of the element 14 are subjected to an intermittent bearing load. The said grooves advantageously as shown have rounded edges and serve to receive lubricant.

Although the bearings of Figures 7, 8 and 9 have been illustrated as including an annular bearing element 14, the latter could, if desired, be replaced by a plurality of angu-

larly spaced bearing elements, as could the element 16 of Figure 8.

Figure 10 illustrates a Michell or Kingsbury tilting pad bearing according to this invention. In this bearing, a shaft 18 carries a thrust collar 19 which bears through tilting pads 20 against sectors 21 in a housing 22. The collar 19 has each bearing face clad with an annular disc-like element 23 formed similarly to the element of any of Figures 1 to 6, the bearing surface of this element being the outer surface thereof. If desired, the collar may be replaced by a plurality of angularly spaced elements.

Figure 11 illustrates a similar bearing to that of Figure 10, but in which, instead of the thrust collar 19 being clad, each of pads 20 has its surface adjacent the collar clad with an element 24 similar to that of the element 23. This figure illustrates how the pads 20 may tilt relatively to the sectors 21.

If desired, the bearing surfaces of the thrust collar 19 may, in a manner similar to the shaft 11 of Figure 9, be radially grooved to ensure that all parts of each element 24 are subjected to an intermittent bearing load.

The surfaces of bearings according to the present invention may, if desired, be used with any type of lubricant liquid. Further, they may be supplied continuously or intermittently with the lubricant by suitable arrangement of a high pressure small delivery pump which can inject the lubricant either through a hole in the surface of the resilient bearing itself or through a hole in the surface which mates with that resilient surface. A hydraulic accumulator may be provided associated with such a pump, whereby low friction may be maintained for long periods of standing while the pump is not running. By these means the bearings of the present invention can be made to support continuous loads.

The bearings of the present invention are capable not only of running under low friction but also of giving a very low starting friction, similar to that achieved with ball bearings. A thrust bearing according to the present invention thus has considerable advantage over the conventional Michell or Kingsbury thrust block.

WHAT I CLAIM IS:—

1. A bearing between two relatively movable members, such bearing comprising at least one element of compressible resilient material carried by at least one of said members, the material of element having therein cavities or channels containing liquid lubricant and opening at a surface remote from the member by which the element is carried, the said surface forming a bearing surface or having thereon a permeable membrane which forms a bearing surface, the arrangement being such that the said element is compressed and the said bearing surface is loaded into engagement with the other of said members or an element thereon, the cavities or channels being such that the lubricant is held therein sufficiently to ensure that the load is borne largely by the lubricant.

2. A bearing according to claim 1, wherein the resilient material is a closed cell sponge rubber or similar sponge material based on a synthetic resinous material.

3. A bearing according to claim 2, wherein channels lead into the body of the material from the said surface thereof and intersect cells within the material.

4. A bearing according to claim 2 or 3, wherein the said material has been cut or trimmed so that some of the cells open at the said surface of the material.

5. A bearing according to any preceding claim, wherein the material has a low permeability in all directions.

6. A bearing according to claim 1, wherein the said material is of a regular cellular structure having cells which have parallel axes extending perpendicularly to the said surface of the material and open at the latter.

7. A bearing according to claim 6, wherein the said cells have a cross-section which decreases in area in a direction away from the bearing surface.

8. A bearing according to any of the preceding claims, wherein the surface of the said other member which is engaged by the bearing surface is shaped to provide an intermittent contact.

9. A bearing according to claim 8 wherein the said member surface is provided with a series of grooves.

10. A bearing according to any of the preceding claims, wherein the said element or elements forms or form a lining of a conventional bearing member.

11. A bearing according to claim 10, wherein the said bearing member is a sleeve and a single element of annular form lines the said sleeve.

12. A bearing according to claim 10, wherein the said bearing member is a sleeve and a plurality of angularly spaced pad-like elements lines the sleeve.

13. A bearing according to claim 11 or 12, wherein the bearing is a shaft bearing, the shaft passing through and rotating within the said lined sleeve.

14. A bearing according to claim 13, wherein the said shaft is, at a position within the said sleeve, clad with one or more elements similar to the lining of the sleeve.

15. A bearing according to claim 12, wherein the bearing is a thrust bearing including a thrust collar which is lined with said element or elements.

16. A bearing according to claim 10 or 15, wherein the bearing is a Michell or Kingsbury tilting pad thrust bearing and

each of the pads of the bearing is clad with one of said elements.

17. A bearing according to claims 9 and 16, wherein the bearing surfaces of the thrust collar of the bearing are radially grooved.

18. A bearing according to any of the preceding claims, wherein the bearing is supplied with lubricant from a pump.

19. A bearing according to claim 18, wherein the said pump has associated therewith a hydraulic accumulator.

20. A method of forming a bearing according to claim 3, such method comprising forming a block of closed cell sponge rubber or similar sponge material based on synthetic resinous material so that this has a surface of the desired shape to form the required bearing surface of the bearing, piercing the said surface so as to provide in the block channels which intersect cells in the block and emerge at the said surface, providing said channels and cells intersected thereby with a liquid lubricant and mounting said block between two relatively movable members so that the block is carried by one of said members and compressed with the said bearing surface loaded into engagement with the other of said members.

21. A method of forming a bearing according to claim 4, such method comprising trimming a block of closed cell sponge rubber or similar sponge material based on synthetic resinous material along a surface in the body of the block intersecting cells therein, providing said intersected cells with a liquid lubricant and mounting said block between two relatively movable members so that the block is carried by one of said members and compressed with the said surface loaded into engagement with the other of said members.

22. A method of forming a bearing according to claims 3 and 4, such method comprising trimming a block of closed cell sponge rubber or similar sponge material based on synthetic resinous material along a surface in the body of the block intersecting cells therein, pressing piercing members into the said surface, to provide in the block channels intersecting cells therein, providing said channels and said cells intersected by the said surface and by said channels with a liquid lubricant and mounting said block between two relatively movable members so that the block is carried by one of said members and compressed with the said surface loaded into engagement with the other of said members.

23. Any of the bearings substantially as hereinbefore described with reference to and as illustrated by the accompanying drawings.

24. Any of the methods of forming a bearing substantially as hereinbefore described with reference to the accompanying drawing.

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960,152
1 SHEET

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

FIG.1.

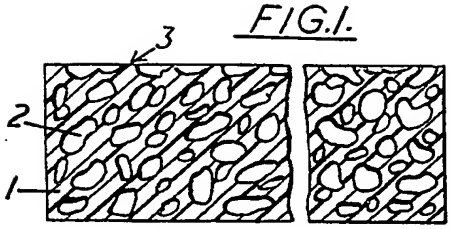

FIG.2.

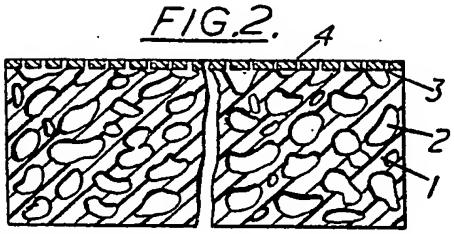

FIG.3.

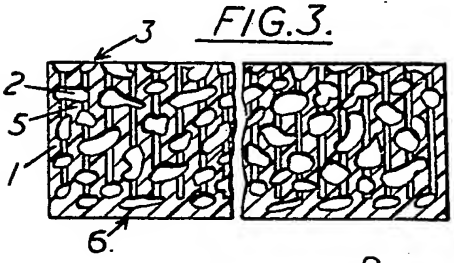

FIG.4.

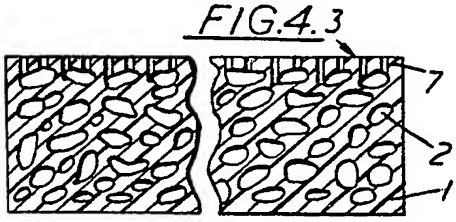

FIG.5.

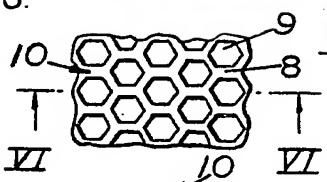

FIG.6.

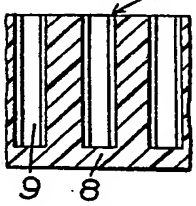

FIG.7.

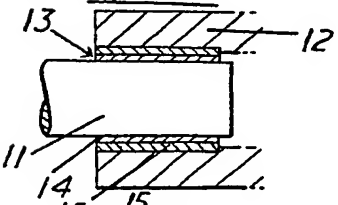

FIG.8.

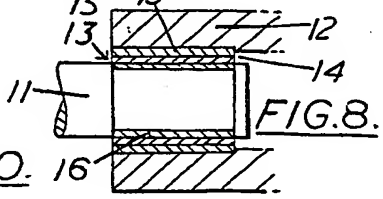

FIG.9.

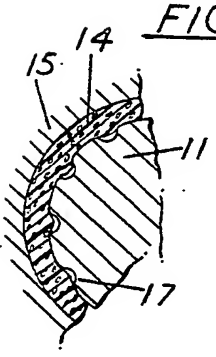

FIG.10.

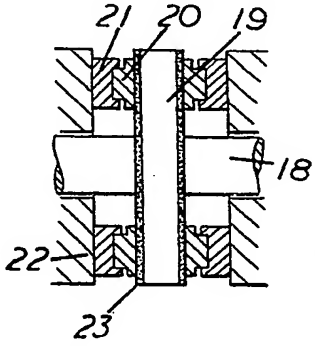

FIG.11.